WHITE PAPER

Next-generation Standards Deliver More Efficient Wi-Fi

Taking Wireless to the Next Level with Wi-Fi 6

Executive Summary

Wireless business models are evolving across industries, with new opportunities being driven by the ability to connect low-throughput devices to Internet of Things (IoT) and serve customers in new ways. At the same time, network engineering and operations leaders are struggling with Wi-Fi performance as wireless LAN density increases. As more devices, users, and applications come on board, wireless traffic will increase exponentially, especially for early adopters of IoT.

The new IEEE 802.11ax standard (often referred to as Wi-Fi 6) can help, improving average throughput per device and increasing overall network efficiency to accommodate the expected influx of devices and the corresponding wireless LAN traffic. As the attack surface expands dramatically due to the explosion in devices coming onto the network, network engineering and operations leaders must adopt flexible, scalable security to protect their Wi-Fi networks.

Solving Wireless LAN Density Challenges

Every network engineering and operations leader knows that Wi-Fi performance is one of the most visible indicators of their effectiveness. If the wireless network is slow, visitors notice, colleagues become frustrated, and the CEO will likely address the issue directly with the network engineering and operations leader or with their manager—typically the CIO or CTO. However, with more users coming online and more wireless-enabled applications and IoT devices consuming bandwidth, Wi-Fi networks are becoming ever more saturated, causing WLAN bottlenecks and poor performance for many networks.

Wi-Fi 6 Innovations

OFDMA: Reduced latency and overall network capacity

BSS coloring: Improved transmission capacity

TWT enhancements: Reduced device contention and higher throughput

1024-QAM: 20% higher data rates than 256-QAM

UL MU-MIMO: Higher overall network throughput

Businesses in various industries are looking to increase Wi-Fi adoption to enable and empower new wireless-driven business models and use cases, both indoors and outdoors, leveraging IoT devices and real-time applications. But these opportunities can only be realized by maintaining a high-quality user experience. Many organizations seek to solve density challenges and support new applications, and new wireless standards are making this possible by increasing capacity and performance.

A Brief History of Wireless Standards

802.11 wireless standards have evolved over the years, offering improvements in speed, range, capacity, and reliability.

Carrier-sense multiple access with collision avoidance (CSMA/CA) has long been used as a network contention protocol for carrier transmission. One key component of this is the idea that a device listens before transmitting, and if it hears another transmission already in progress (above a standardized signal level), it will wait. However, the technology has its limitations in crowded environments, where many users are trying to access the wireless network at once. With too much congestion, transmissions can be significantly delayed.

The initial Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard offered 1 or 2 Mbps transmission speeds in 2.4 GHz and used frequency-hopping spread spectrum (FHSS) and direct-sequence spread spectrum (DSSS) technologies.

Since 1999, new IEEE 802.11 standards have been released every few years, each offering incremental improvements:

- 802.11a (1999) used orthogonal frequency-division multiplexing (OFDM) with a specified theoretical speed of up to 54 Mbps in the 5 GHz band.
- 802.11b (1999) used DSSS and provided a maximum theoretical rate of 11 Mbps.
- 802.11g (2003) used the same OFDM technology that was introduced in 802.11a, but operated in 2.4 GHz and supports speeds up to 54 Mbps.
- 802.11n (2009) increased throughput in both the 2.4G Hz and the 5 GHz frequency ranges, improved the theoretical data rate to 300 Mbps, and introduced multiple input multiple output (MIMO), a significant change to the standard which unlocked throughput levels previously out of reach.

- 802.11ac (2014) achieved high throughput in the range of Gigabits per second. 802.11ac uses the 5 GHz band and supports up to eight spatial streams. It also introduced beamforming and multi-user MIMO (MU-MIMO).

Wi-Fi 6 to the Rescue

IEEE 802.11ax (also called High-Efficiency Wi-Fi and dubbed Wi-Fi 6 by Wi-Fi Alliance) is poised for widespread adoption, improving average throughput per device and increasing overall network efficiency. Put simply, it is a great way to get a lot of low-throughput devices (such as IoT devices) onto the network.

Unlike 802.11ac, Wi-Fi 6 is supported on both 2.4 GHz and 5 GHz frequency bands, making it a more versatile standard. The main goal is to improve the average throughput per user in dense user environments. Wi-Fi 6 promises a better Wi-Fi experience, especially in IoT, outdoor, and high-density environments such as schools, entertainment venues, and stadiums.

From a technical perspective, the new standard brings the following benefits:

- **Orthogonal frequency-division multiple access (OFDMA).** 802.11ax uses OFDMA as the modulation and access scheme in which the subchannels are further divided into subcarriers called resource units (RU). The access points (APs) allocate the RUs to multiple clients or a single client, depending on the traffic. This allows the devices to share the channel and make more effective use of the RF spectrum, thereby reducing overhead and latency and increasing the overall capacity of the network (see Figure 1). During OFDMA transmission periods, the AP coordinates both the uplink and downlink OFDMA allocations. On the right, the resource units have been assigned to User 0 and User 1, while the third subchannel has been completely assigned to User 0, and so on.

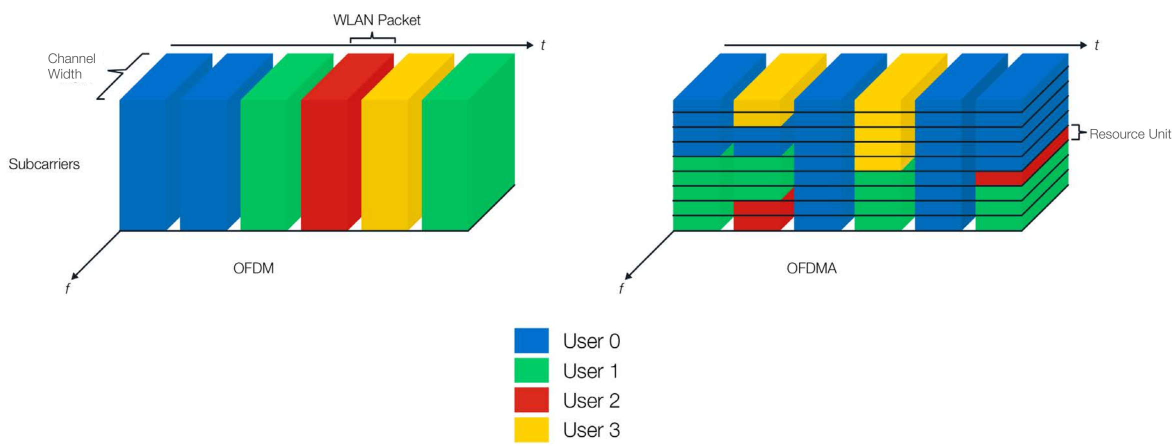

Figure 1: A comparison of orthogonal frequency-division multiplexing (OFDM) and orthogonal frequency-division multiple access (OFDMA) modulation schemes.

- **Basic service set coloring (BSS coloring).** In dense deployments, the same channels are often reused due to the limited spectrum and are separated by a certain distance to reduce interference. When the APs and clients hear each other in the same channel, there is a contention overhead called co-channel interference (CCI) or overlapping basic service set (OBSS). When CCI occurs, the AP cannot transmit, and all the clients associated with the AP also defer transmission. This causes media contention and can cause overall loss of throughput.

  With BSS coloring, 802.11ax adds a color or identifier to each AP so that APs using the same channel can decide if they can transmit simultaneously (see Figure 2). When a radio hears another transmission, it will check not only the signal strength (as it did before) but also the BSS color of the transmitting radio. Transmissions of a different color have a new higher signal strength threshold that will trigger a “wait” condition. This opens up more windows to communicate and hence improves the overall capacity, especially in dense networks such as stadiums and performance venues. Allowing frequency reuse between BSS further increases network efficiency by allowing concurrent data transmission.

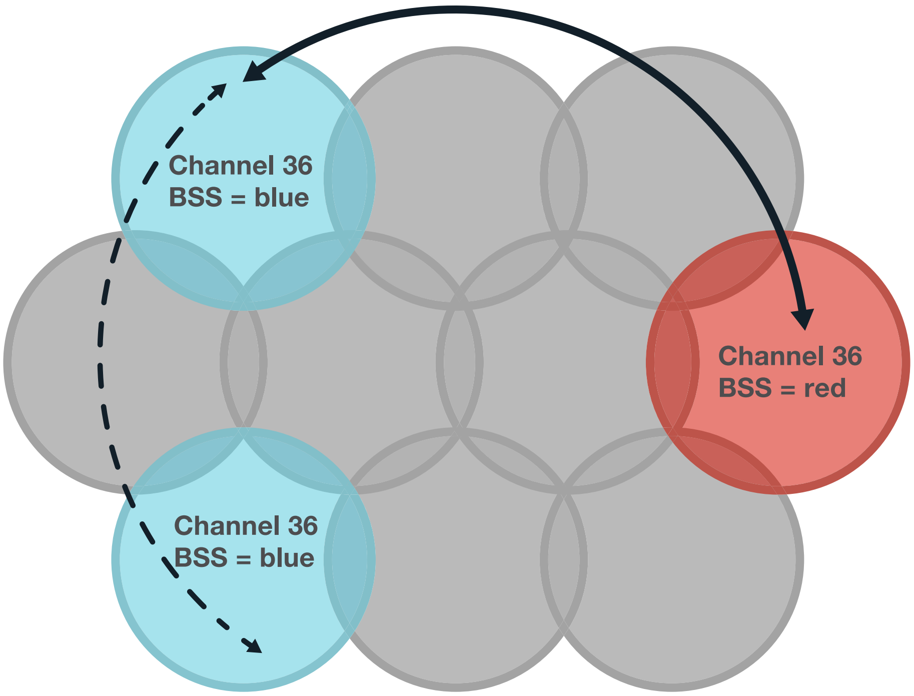

Figure 2: Using BSS coloring to distinguish between APs using the same channel, OFDMA can trigger a higher wait threshold, thereby improving transmission capacity.

- **Target wake time (TWT) enhancements.** Useful in both mobile and IoT environments, TWT increases device sleep time and helps improve battery life by providing an effective mechanism to schedule transmission in time. Before TWT, the 802.11 specification relied on "power save mode," which allows devices to sleep for a certain amount of time until the AP is ready to send the buffered data to the client. However, this method is not very efficient, since the sleep interval is small and only suitable for light traffic conditions.

  With 802.11ax, TWT enhancements allow radios to negotiate a longer sleep time between transmission. The APs can further negotiate with each mobile device and schedule access times. This reduces contention between devices and increases network throughput (see Figure 3).

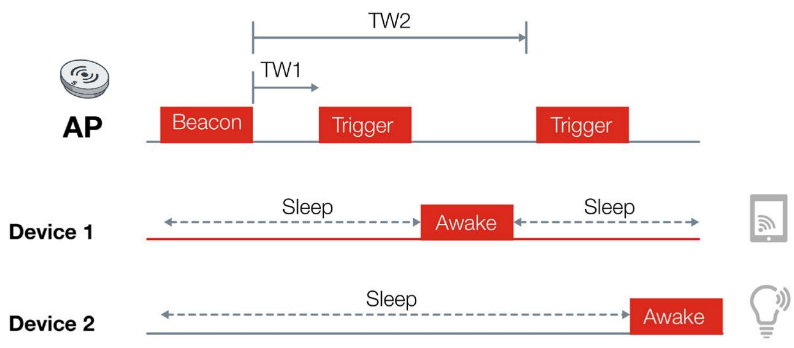

Figure 3: Negotiating device wake times reduces contention and increases throughput.

- **1024 quadrature amplitude modulation (QAM):** Approximately 20% higher throughput is achieved by moving from 256-QAM in 11ac to 1024-QAM in 802.11ax.[1] Introduced in 802.11ac, 256-QAM maps 8 bits per carrier, and 802.11ax increases this to 10 bits. Since more bits are packed per carrier, it makes efficient use of the spectrum and increases the theoretical data rate to 25%.[2] However, with the increase in the number of bits per carrier, transmission is more susceptible to the noise. This means that a better receiver is required that also consumes more power, which has been true of every standard released by the IEEE since 1999. Figure 4 shows a comparison of constellation charts between 256-QAM and 1024-QAM modulation density.
- **Uplink multi-user MIMO (UL MU-MIMO).** 802.11ac defined only downlink MU-MIMO, where the AP transmits multiple spatial streams to multiple client devices simultaneously. 802.11ax extends it to uplink for increased overall network throughput, supporting up to 8x8:8 MU-MIMO in both uplink and downlink (see Figure 5).

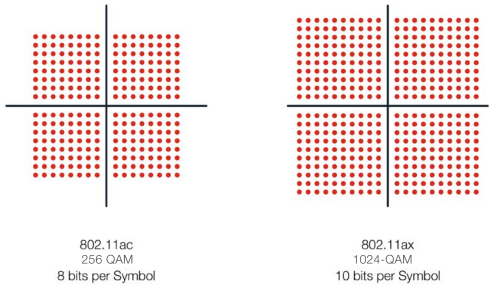

Figure 4: A comparison of constellation charts between 256-QAM and 1024-QAM modulation density.

CSMA/CA is vulnerable to congestion in crowded environments. The new Wi-Fi 6 (802.11ax) standard includes multiple innovations to overcome contention and capacity issues.

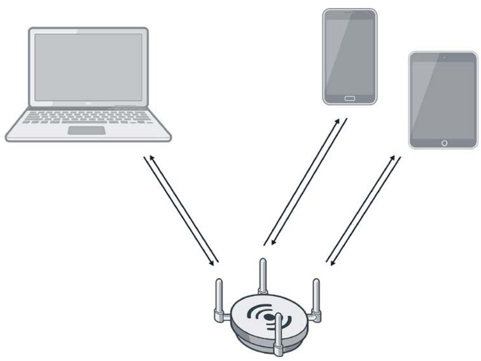

Figure 5: In 802.11ax, MU-MIMO works in both downlink and uplink directions.

Is There Any Downside?

Network engineering and operations leaders pay no penalty for upgrading to the new standard. The only downside is that a resulting explosion of IoT and other network devices in the coming years could very well slow a Wi-Fi 6 network down again, negating some of the performance gain. But that is no reason not to upgrade now.

The very real risk in not adopting Wi-Fi 6 is that network performance will continue to decline as traffic increases, and the business will not be well-positioned to pursue new wireless opportunities. Soon, there will be billions more IoT devices, from connected cars to sensors on home appliances. More business applications will leverage these devices and use wireless networks for location awareness. Investing in 802.11ax will certainly provide value, as it is the future of wireless networking.

More Devices Require More Security

As Wi-Fi 6 adoption allows more devices onto corporate, public, and private government networks, this additional traffic will require new approaches and increased vigilance around wireless security. Given the increasing importance, usage, and user expectations of wireless networks, wireless security should be top of mind for every network engineering and operations leader.

[1] Mark Turner, "Wi-Fi 6 Explained: The Next Generation of Wi-Fi: What Does 802.11ax Bring to the Table?" Techspot, December 24, 2018.

[2] Ibid.

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